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NRL Memorandum Report 3985

Sonar Transducer Reliability Improvement Program FY 79

Second Quarter Progress

R. W. TIMME

Materials Section
Transducer Branch
Underwater Sound Reference Detachment
P.O. Box 8337, Orlando, Fl 32856

April 1, 1979

NAVAL RESEARCH LABORATORY
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Progress accomplished during the Second Quarter of FY79 in the Sonar Transducer Reliability Improvement Program is reported. Each of the nine program tasks are discussed in some detail. The most significant aspects are failure modes in the new TR-215 ( ) transducer design and the testing techniques used to discover them, the problem of not being able to measure very low background noise, the quantification of corona levels on ceramic, and the development of the sleeve spring pressure release mechanism.

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Sonar Transducer Reliability Improvement Program

NRL Problem 82 S02-43

FY79 Second Quarter Report

1. INTRODUCTION

1.1 PROGRAM OVERVIEW

The general objective of this program is to perform relevant engineering development which addresses the operational requirements for fleet transducers for active sonar, passive sonar, surveillance, countermeasures and deception devices, navigation, and acoustic communications. The approach is to develop, test, and evaluate improved transducer design, materials, components, and piece parts that will meet specified requirements in the operational environment during the entire useful life of the transducer. Standards will be prepared to ensure that results obtained during preliminary testing will be obtained consistently in production. This program should result in improved performance and reliability and reduced costs through better utilization and a more comprehensive characterization of materials and design data. The program goals are as follows:

a. *Reduction in transducer replacement costs*

Goal - less than 9% of population replaced each year with no automatic replacements at overhaul

Threshold - less than 18% of population replaced each year

b. Improvement in transducer reliability

Goal - less than 1% of population failures each year

Threshold - less than 3% of population failures each year

c. Improvement in transducer receiving sensitivity

Goal - less than ±1 dB variation from the specified value over operational frequency band

Threshold - less than ±2 dB variation from the specified value over operational frequency band

d. Reduction in transducer radiated self-noise

Goal - 30 dB reduction

Threshold - 20 dB reduction

The Sonar Transducer Reliability Improvement Program (STRIP) is a part of Program Element 64503N. Major task areas with specific objectives to achieve the program goals have been described in the Program Plan and include:

Task Area A. Encapsulation Methods
Task Area B. High Voltage Engineering
Task Area C. Cables and Connectors
Task Area D. Transducer Material Standards
Task Area E. Environmental Test Methods
Task Area F. Noise and Vibration
Task Area G. Transducer Tests and Evaluation

The FY79 program plan for STRIP has been funded at the $495 K level. The specific tasks and their Principal Investigators for FY79 are listed below:

	Task	Principal	Investigator
A-1	Fluids and Specifications	NRL	C.M. Thompson
B-1	Corona Abatement	NRL	L.P. Browder
C-1	Cables and Connectors	TRI	J.S. Thornton (D. Barrett)
D-1	Materials Evaluation	NUSC	C.L. LeBlanc
E-1	Standard Test Procedures	NOSC	G.L. Kinnison (J. Wong)
F-1	Noise and Vibration	NOSC	C. Bohman
G-1	Sleeve Spring Pressure Release	TRI	J.S. Thornton (L. Smith)
G-2	Test and Evaluation	NRL	A.M. Young
G-3	Engineering Documentation	NWSC	D.J. Steele (D. Moore)

1.2 SUMMARY OF PROGRESS

During the Second Quarter of FY79, efforts in the various tasks of STRIP have resulted in progress toward the program goals as summarized below:

a. The application of the concept of accelerated life testing of sonar transducers continues on the TR-215 ( ) transducers (AN/BQS-8/10/14/20). Important failure modes have been discovered, the most recent being a serious temperature increase under high drive conditions. There should be an increasing concern whether the new TR-215 ( ) design will be sufficiently reliable. See Section 6.3.

b. Evidence is being found that the ability to measure very low background noise is limited by the noise making characteristics of the monitor hydrophones themselves. See Section 7.3.4.

c. Development of the concept of the sleeve spring as a pressure release mechanism is nearing completion. Retrofit into TR-155 transducers is being made for test and evaluation. See Section 8.3.

d. The quantification of corona levels and drive voltages has been determined for one configuration of ceramic transducer element. See Section 3.3.3.

e. The annual review for the STRIP was held 14 March 1979 in the TRACOR Conference Room, Rockville, MD. The 53 in attendance represented a cross-section of the sonar community -- program managers, sonar engineers and designers, transducer restoration engineers, and scientists:

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1.3 PLANS

The program plan for the FY80 STRIP is currently being revised and will be presented to NSEA in May 1979.

1.4 REPORT ORGANIZATION

The remaining sections of this quarterly report will discuss the objectives, progress, and plans for the specific tasks included in the STRIP.

2. TASK A-1. TRANSDUCER FLUIDS AND SPECIFICATIONS

2.1 BACKGROUND

A material to be used for filling a sonar transducer must meet a wide variety of specifications. The requirements imposed by the electrical nature of the device include high resistivity, high dielectric constant, as well as resistance to corona and arc discharges. The water environment of the transducer necessitates low water solubility and other attractive solution properties. In addition, the fluid must maintain its electrical and other properties in the presence of any water which permeates the covering. The acoustic requirements are a close acoustic impedance match with sea water and resistance to cavitation at high drive levels. Other obvious properties include compatibility with other components, stability to degradation, suitable surface tension, and viscosity.

With such a wide variety of requirements, it is not surprising that compromises have to be made. The most commonly used fluid for many years has been castor oil. This use is in spite of its high viscosity. Each of the fluids proposed, so far, as a replacement has serious drawbacks. Silicone oils tend to creep onto and wet all of the surfaces of the transducer. This greatly complicates bonding the components together. Polyalkylene glycol (PAG) has the disadvantages of a high water solubility and low electrical resistivity. The various hydrocarbon liquids have too low an acoustic impedance and are frequently incompatible with the various plastics and rubbers in the transducer. Further research is necessary to find and qualify fill fluids which represent the best match to all the requirements imposed upon it.

2.2 OBJECTIVES

The objectives of this task are:

a. To find plausible new transducer fill fluids which combine all the best properties. Candidates include: hydrophobic polyethers, sterically protected esters, chlorine - or fluorine - containing hydrocarbons, methyl alkyl silicones, and possibly aromatic hydrocarbons.

b. To apply the criteria developed during the PAG and castor oil testing to the most promising candidate fluids.

2.3 PROGRESS

2.3.1 Polytetramethylene glycol (PTMG) is a commercially available polyether compound. Commercial PTMG contains two hydroxyl functional groups which greatly influence its properties and reduce its usefulness as a transducer fluid. The modification of PTMG should provide a material with the advantages of polyalkylene glycol (such as viscosity, sound speed, PVT relations, compatibility), but without some of the critical disadvantages. The proposed modified PTMG has a lower proportion of ether-type oxygens than PAG. This will reduce the polarity of the molecule

and result in decreased water solubility parameters. The increased separation between oxygen atoms eliminates the problem of chelation of metal ions discovered in PAG.

The modification of PTMG involves the elimination of the hydroxyl end groups by reduction or by "capping" them with alkyl groups. Earlier attempts at both methods met with only limited success. During this quarter a reverse Williamson ether synthesis was successfully carried out on PTMG. This involved chlorination with thionyl chloride followed by reaction with sodium methoxide. These reactions have been carried out with fair yield. Attempts are now underway to purify the product. Investigations are also underway into methods of preparation that will increase the yield and decrease the cost of preparation of modified PTMG.

2.3.2 The previous measurements on the vapor pressure-water content of PAG are being repeated because of the importance of these data. Significant differences in the shape of the curve and the saturation limits from those previously determined have led to a further investigation into the decomposition of PAG. The preliminary indication is that PAG does undergo air oxidation which leads to a drastically increased water solubility limit. Investigations are now in progress into the effect on the transducer-related properties due to this decomposition.

2.3.3 A promising transducer fluid for special applications is methyl alkyl silicone. This material differs molecularly from the familiar [read infamous] dimethyl silicone such as DC200. The alkyl side groups of alkyl methyl silicone confer more hydrocarbon-like properties on this material. Although the density and sound speed for this material are somewhat low, it has many of the important advantages of dimethyl silicones which have been used in the past. Reportedly, however, methyl alkyl silicone does not have as high a tendency to creep over and wet surfaces. An attempt is now underway to quantify this tendency for the various fluids so that this parameter will not be ignored in future candidate fill fluids. The approaches are:

a. Measure surface tension by capillary-rise method;

b. Measure bond failures with wetted surfaces using peel tester. Correlations of these results with the previous history of bond failures in the presence of dimethyl silicone will then be attempted.

If methyl alkyl silicone is satisfactory in these tests, further qualification tests will be performed.

2.3.4 The interactions between sea water and plastomers, encapsulants, and plastics are a potential source of failure in any sonar transducer. The rapid degradation of the polyester types of polyurethanes provide a glaring example of this mode of failure. A preliminary study has begun with several compounds of each type exposed to both salt and fresh water with some studies also performed at elevated temperatures. Weight change,

swell, and hardness change are being monitored. No distinct trends are apparent at this early stage of the testing (2 weeks).

2.4 PLANS

2.4.1 Write memorandum report on the observed degradation of PAG. (18 May 1979)

2.4.2 Complete report on rate of water permeation into oil-filled transducer. (29 June 1979)

2.4.3 Perform physical, acoustic, and chemical tests on modified PTMG. (31 July 1979)

2.4.4 Continue tests on methyl alkyl silicones and begin tests on fluorinated hydrocarbons.

2.4.5 Continue the test on the effects of water on polymers.

3. TASK B-1 CORONA ABATEMENT

3.1 BACKGROUND

A significant percentage of transducer failures is due to voltage breakdown of insulating materials developing from corona erosion mechanisms. It is not practical to test the end item (transducer) to quantify the effects of corona erosion on transducer reliability and lifetime. Corona must be studied as a failure mechanism at the component or piece part level to quantify the protection requirements and establish reliability factors. Transducer reliability may then be achieved by control of design parameters and construction processes.

3.2 OBJECTIVES

The objectives of this task are:

a. To provide consultation in selecting materials useful in corona abatement for sonar transducers.

b. To reduce corona and flashover damage by quantifying voltage breakdown levels with various design parameters that may be specified and controlled.

c. To study the insulating properties and corona resistance of the piezoelectric ceramic material that is an essential part of sonar transducers.

d. To identify and test various thin films and coatings with high dielectric strength to establish their usefulness at reducing corona.

e. To determine the quality control factors to be considered for corona abatement materials and methods selected for use in transducers.

f. To provide guidance for establishing general specifications for corona abatement and high voltage design and construction.

3.3 PROGRESS

3.3.1 A gas test chamber was designed and constructed for use with the Biddle corona detector to provide corona evaluation data with various simulated transducer assemblies. The two-liter test chamber and its associated gas handling system allows control of the gas composition, pressure and humidity. Tests indicate the assembly is corona-free to a voltage level of 25 kV rms.

3.3.2 Tests were made of the change of corona inception voltage (CIV) of wet and dry air using the point-to-plane electrode configuration. Nominal results for ambient room air were presented as Figure 3.1 of the

previous progress report [1], where the relative humidity (R.H.) at 25°C was approximately 60%. The new data for 2% and 95% R.H. indicates a lower CIV for wet air in all tests. The amount of difference ranges from 4-15% with the greatest change for points with the smallest radius of curvature. Another characteristic observed for corona in wet air is a larger number of corona bursts per unit of time.

3.3.3 A series of tests were made on ten (10) discs of Gulton G1408 PZT ceramic with a diameter of 2.54 cm (1 in.) and thickness of 1.27 cm (½ in.) to establish average corona and flashover effects on the clean, dry material. Table 3.1 summarizes the results. Flashover in wet air was about 3% higher than for dry air, but the CIV was about 40% lower. A transducer constructed using a parallel assembly of these discs would have a CIV at the lowest worst-case condition and would vary with the R.H. of the surrounding air.

R.H. of Air at 25°C	CIV (kV)		Flashover (kV)	
	Avg.	Std. Dev.	Avg.	Std. Dev.
<1%	6.16	1.80	12.76	1.02
95%	3.45	1.19	13.13	.72

Table 3.1 Ceramic corona in wet and dry air

Between the CIV and flashover levels the corona discharge magnitude increased in step increments of an order of magnitude (10/1) or more at 2 or 3 drive voltage levels. Figure 3.1 illustrates a representative function of corona discharge level in picocoulombs (pC) with ac drive voltage. In any specific case, the corona levels were observed to be highly variable even when the drive voltage was maintained constant or the test was repeated on the same sample of PZT. Flashover was always on the ceramic surface between electrodes and a straight dark line was burned.

It should be recognized that in the implementation of a useful corona specification for sonar transducers, ambient room air is the most economically feasible and practical dielectric gas to use. These results of CIV relative to R.H. indicate a possible wide variation of test results from day-to-day depending on the water content of the air. Reproducible CIV measurements may only be obtained by the control and measurement of the water vapor content. Interpretation of the results in terms of transducer reliability will require evaluation of the partial pressure of the water vapour, so that both R.H. and temperature need to be recorded.

[1] STRIP First Quarter Report, Task B-1, January 1979

3.3.4 A limitation of the high voltage test chamber being used is that it has no provision for mechanical bias stress to avoid fracturing the ceramic. Therefore, some of the test samples split when voltage breakdown occurred. Microscopic examination of the failed samples revealed that the fractures developed from a gas void near the geometric center of the discs. One of the voids was an oval shape of dimensions 2x1x1 mm. The fracture plane tended to favor locations where other tiny voids were positioned. This makes it possible to estimate that the average diameter of the small voids was 0.02 mm and distribution was approximately uniform throughout the sample. The average distance between voids was about 0.5 mm which would indicate nearly 8000 voids/cm^3 and accounts for 0.003% of the volume. In the technical literature, corona has been reported to be associated with internal voids of this nature, but there was no indication in these tests that would isolate this to be a factor because the test was too short.

3.4 PLANS

3.4.1 Measure corona inception voltage and flashover voltage on ceramic discs using wet and dry sulfur hexafluoride (SF_6) as the insulator gas.

3.4.2 Adapt the gas test chamber to test the corona resistance of PZT ceramic using the general procedures of ASTM D495-73, Standard Test Method for High-Voltage, Low-Current, Dry Arc Resistance of Solid Electrical Insulation, and evaluate the ceramic lifetime function in dry air.

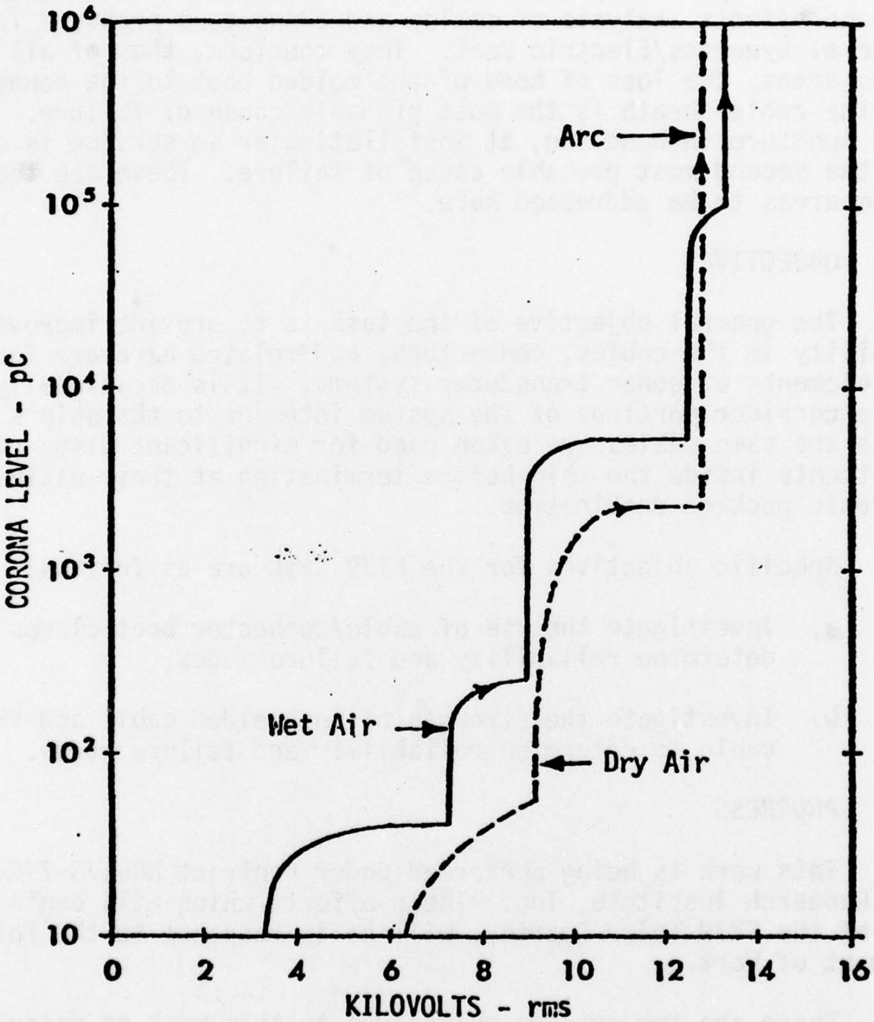


Figure 3.1

PZT CERAMIC CORONA IN AIR

4. TASK C-1. CABLES AND CONNECTORS

4.1 BACKGROUND

The use of cables and connectors is an area of concern for long-term sonar reliability because of a history of failures. Deficiencies can be generally categorized in the four areas of: design of cables and terminations; specification and testing; handling; and repair and maintenance. Specific problems have been identified in a recent failure modes and effects analysis of cables and connectors prepared for NAVSEA by General Dynamics/Electric Boat. They conclude, that of all the problem areas, the loss of bond of the molded boot to the connector shell or to the cable sheath is the most probable cause of failure. Cable jacket puncture in handling, at installation or in service is considered to be the second most probable cause of failure. These are the two problem areas to be addressed here.

4.2 OBJECTIVES

The general objective of the task is to provide improved reliability in the cables, connectors, and related hardware for the outboard elements of sonar transducer systems. It is occasionally necessary to also consider portions of the system interior to the ship's hull because the same cables are often used for significant distances through compartments inside the ship before terminating at their ultimate electronic package destination.

Specific objectives for the FY79 task are as follows:

a. Investigate the use of cable/connector boot clamps to determine reliability and failure modes,

b. Investigate the strength of unshielded cable and shielded cable to determine reliability and failure modes.

4.3 PROGRESS

This work is being performed under Contract N00173-79C-0129 by Texas Research Institute, Inc. Their effort, which will begin at the start of the FY79 Third Quarter, will be in response to the following Statement of Work.

There are two primary objectives to this work as described below:

<u>OBJECTIVE 1</u>

Investigate the use of cable/connector boot clamps to determine reliability and failure modes.

Successful completion of this objective should provide quantitative answers to the following questions:

1. Does the clamp or band concept prevent leakage in the extreme case where the boot is not bonded to the Portsmouth connector backshell or the cable?

2. Does a clamp lose its effectiveness with time, temperature, and pressure?

3. What is the best clamp type and material of the various possibilities?

4. Does a clamp decrease the degradation rate of a bond between boot and connector backshell or cable?

5. What is typical lifetime for an unclamped bond between boot and connector backshell or cable?

6. What degree of improvement can be expected from the use of clamps in terms of increased life and decreased initial rejection rates?

7. What is the cost benefit of using clamps to increase reliability in terms of price, manpower, change in lifetime, etc?

The approach to the accomplishment of these objectives will be a series of controlled laboratory pressure and temperature tests to determine the effect of many cycles on clamped systems compared to bonded and unbonded systems. Preliminary lab tests should be able to verify the performance of these clamps by using them over boots which are not bonded at all. A series of accelerated aging tests will also be run. The variables to be included in the test are the elastomeric boot material (neoprene and urethane) and the clamp/band type and material (field installable types such as Band-its, hose clamps, cable ties, filament wraps, etc., and shop installations such as crimp rings, etc).

OBJECTIVE 2

Investigate the strength of unshielded cable and shielded cable to determine reliability and failure modes.

Successful completion of this objective should provide quantitative answers to the following questions:

1. What forces do cables experience during installation, ship operations, and maintenance?

2. Does the shield provide additional tensile or crush strength and resistance to failure?

3. Does a shield provide any protection from puncture or does it contribute to failure by abrading the insulation?

4. What is the cost and reliability tradeoff of shielded versus unshielded cables?

This approach to the accomplishment of these objectives will contain an analysis of operations including measurements to determine the loads which cables experience during cable-pulling operations and when used as steps and handholds. Simple instrumentation of the actual pulling processes in a shipyard and some mock-up tests of step loads will provide documentation of the kinds of loads which these cables really must handle during installation and maintenance operations. A basic strength test program will be run which would involve testing of at least the basic types of cable presently in use, such as:

a. DSS, DSU, FSS, FSU with several different conductor sizes, single and double jacketed, as commonly used in fleet sonar.

b. Polyurethane cable with Tefzel conductor insulations, as planned for use in Trident.

c. Assorted commercial cables which are non-MIL-SPEC as appropriate.

The tests will be, at least, in the three areas of straight pull, pull while bent around the rated minimum bend radius, and crush such as by a dropped tool and pressure from being stepped upon by work shoes. The properties to be measured will include electrical performance, yield strength, break strength, and others, as appropriate.

4.4 PLANS

Work will start 6 April and is scheduled for completion in 9 months.

5. TASK D-1. MATERIALS EVALUATION

5.1 BACKGROUND

Pressure release materials are used to mechanically and/or acoustically isolate some components of sonar transducers to improve overall acoustic performance. Normally the pressure release materials must operate effectively under bias stress anywhere from 50 psi to 3 kpsi over a discrete temperature range, e.g., 5°C to 40°C. To predict performance it is essential to know the properties of the materials under the imposed constraints. Previous measurement methods for determining the properties of some pressure release materials, such as Sonite (an asbestos - glass fiber composite), onion-skin paper, syntactic foams, Hytrel (a thermoplastic polyester elastomer), etc., have given relative results with a hydraulic press or bulk effects with an impedance tube. There is a strong need to correlate existing measurement data and to establish a standard measurement system to be used by the Navy for incorporation into specifications and/or acceptance tests on pressure release materials.

An additional problem is that pressure release materials absorb the transducer fill fluids. This process increases the acoustic impedance of the pressure release material and thus reduces the effectiveness of its acoustic insulation. Degradations of from 3 dB in 3 years to 6 dB in 10 years have been reported in transducers in the field, and attributed to changes in the pressure-release material.

There are thus two phases to this task: the material characterization phase; and the fluid absorption phase.

5.2 OBJECTIVES

The objectives of this task are:

a. To initiate and evaluate a standard dynamic measurement system for determining the properties of pressure release materials over the ranges of stress from 50 psi to 3 kpsi and at temperature from 5 to 40°C.

b. To measure and evaluate candidate pressure release materials, such as Sonite, onion-skin paper, corprene, etc.

c. To quantify the changes in acoustic properties of cork-rubber composites as they absorb transducer fill fluids.

d. To develop a math model that will predict changes in the acoustic properties of cork-rubber composites with time (and in turn predict changes in transducer directivity and sensitivity).

e. To identify the specific problems with DC-100 which may eventually lead to its replacement with a more suitable material.

5.3 PROGRESS

5.3.1 A standard dynamic measurement system consisting of a double mass-loaded longitudinal resonator (tonpilz driver unit) and a detachable sample holder, as shown in Figure 5.1, was assembled. The pressure release sample and loading mass are connected in tandem and bolted into the head mass with a separate stress rod to control the static stress level on the pressure release material. An accelerometer, not shown in Figure 5.1, is bonded to the front end of the loading mass and the accelerometer output is monitored as the ceramic stack is driven electrically with a signal generator. Initial measurement results, shown in Figure 5.2, indicate that the complex material parameters of pressure release materials, as well as other elastomeric transducer materials, can be evaluated by directly measuring the low-frequency (l.f.) resonance and quality factor, Q, associated with the unknown pressure release sample and loading mass. As shown in Figure 5.2, the main resonance frequency of the overall composite structure is altered only slightly by variations in the compliance properties of the unknown pressure release sample, whereas the associated low-frequency resonance is changed substantially by altering the stress level (uncalibrated in the example shown in Figure 5.2) on the unknown sample. The mechanical quality factor is determined from the frequency spread of the peak response at the 3 dB-down points. The low-frequency resonances are controlled by the value of the loading mass, heavy or light; but the low-frequency resonance should be kept well below the main composite transducer resonance for reliable analysis of the pressure release material properties.

The properties may also be determined by monitoring the magnitude and phase of the velocities at either end of the pressure release sample, i.e., assuming one knows the properties of the stress rod material.

A block diagram of the complete mechanical measurement system is shown in Figure 5.3 and each element in the diagram can be represented in the usual equivalent circuit.

A generalized math model was developed to predict the complex (real and imaginary) elastic properties of the pressure release materials. The general math model was reduced using normal low-frequency approximation methods to enhance calculations from measurement data. The model must now be programmed for simple computer operation, e.g., the Hewlett Packard 97 Calculator, to avoid extensive and expensive computer time. In addition, computer analysis of the complete assembly from the electrical driving port should also yield the properties of the pressure release materials.

5.3.2 Although the most commonly used pressure release cork-rubber composite is the Armstrong DC-100, a cork-neoprene mixture (corprene), other composites are also produced by Armstrong which may, in fact, have superior properties. Selections of these materials are being immersed in castor oil, silicone oil, and polyalkylene glycol, and the permeation of the fluid is being monitored microscopically and gravimetrically. Thin sectioning and microscopic analysis have been carried out on samples in preparation for up to 10 months. In this set of tests, samples are sectioned on a microtome and weighed. This indicates the degree of

saturation at a given depth of oil penetration. Figure 5.4 is a graph obtained from the sectioning and weighing of DC-100 immersed in castor oil. The elapsed time for this particular sample was 10 months, at a temperature of 75°C. From Figure 5.4, it is evident that three distinct regions exist. An area of 100% saturation, an area of decreasing saturation, and an unsaturated area. All samples tested follow this general pattern with differences in slope at the transitional line and depth of penetration at a given time. When observed by the sectioning technique DC-100 appears to be more predictable than NC-710. NC-710 did not show as well-defined a fluid front as did DC-100. Instead "fingers" of saturated material were protruding past the fully saturated material leaving a very poorly defined fluid front. This could make an accurate mathematical model of the changes in acoustic properties with oil saturation of NC-710 impossible.

The gravimetric analysis of oil permeation has now been conducted for 10 months (7200 hours). Most of the composites are being tested with most of the fill fluids over a range of temperatures.

5.4 PLANS

5.4.1 The next quarter's work will be to build the supporting structure to freely suspend the mechanical measurement system, instrument the system with the necessary strain gauges, accelerometers, and monitoring equipment, and make measurements of known materials to verify the math models.

5.4.2 Gravimetric and microscopic analyses will continue.

5.4.3 Impedance tube samples have been prepared and testing will start April 1979.

5.4.4 With information accumulated from the above tests, a math model will be formulated and tested on a transducer element. Recommendations will be made about either a better pressure release material, a method to minimize changes in existing materials or a way to compensate for changes.

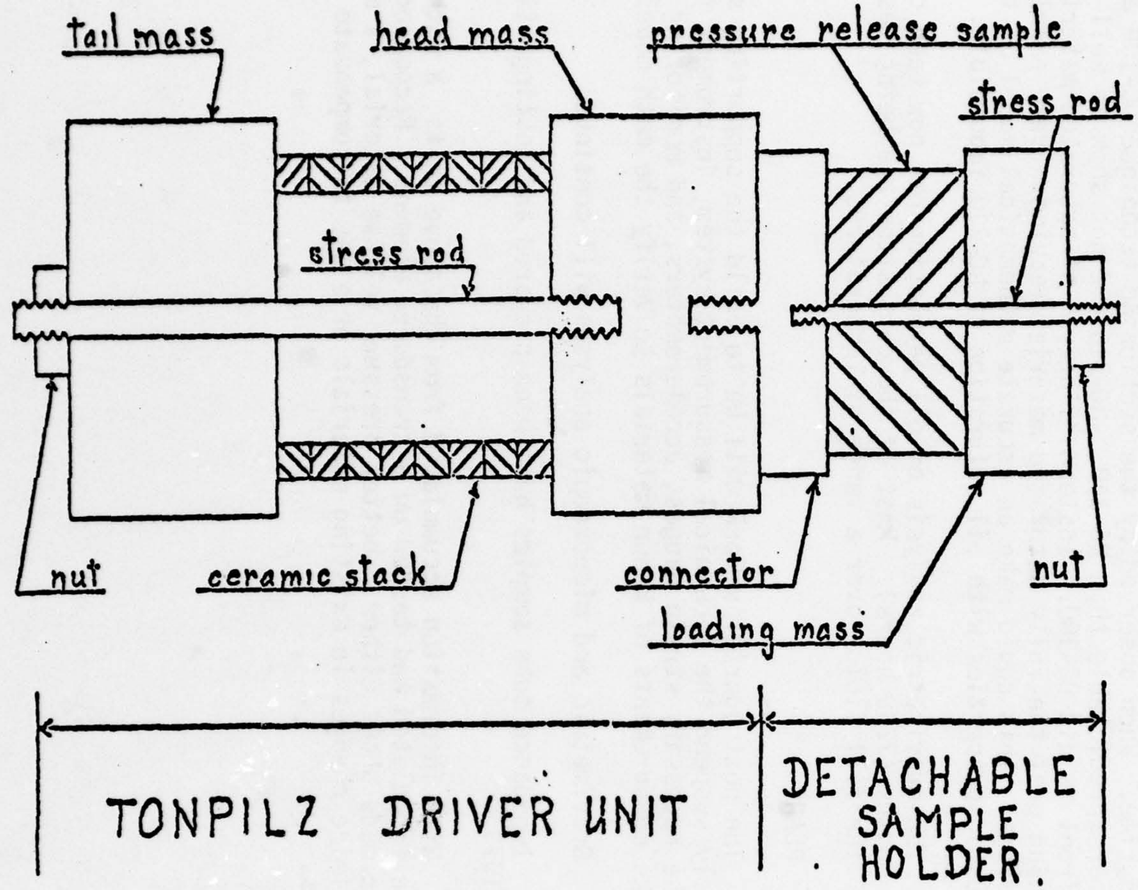
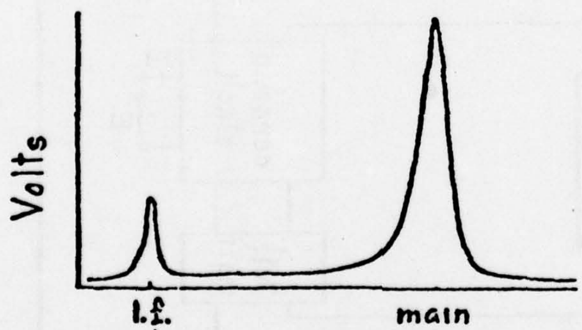


Figure 5.1
MEASUREMENT ASSEMBLY

Resonance Frequencies
(in kHz)

loading mass / stress level	heavy		light	
	l.f.	main	l.f.	main
high	1.09	3.58	1.41	3.57
low	.58	3.54	.62	3.53



Relative Response

Figure 5.2
MEASUREMENT RESULTS

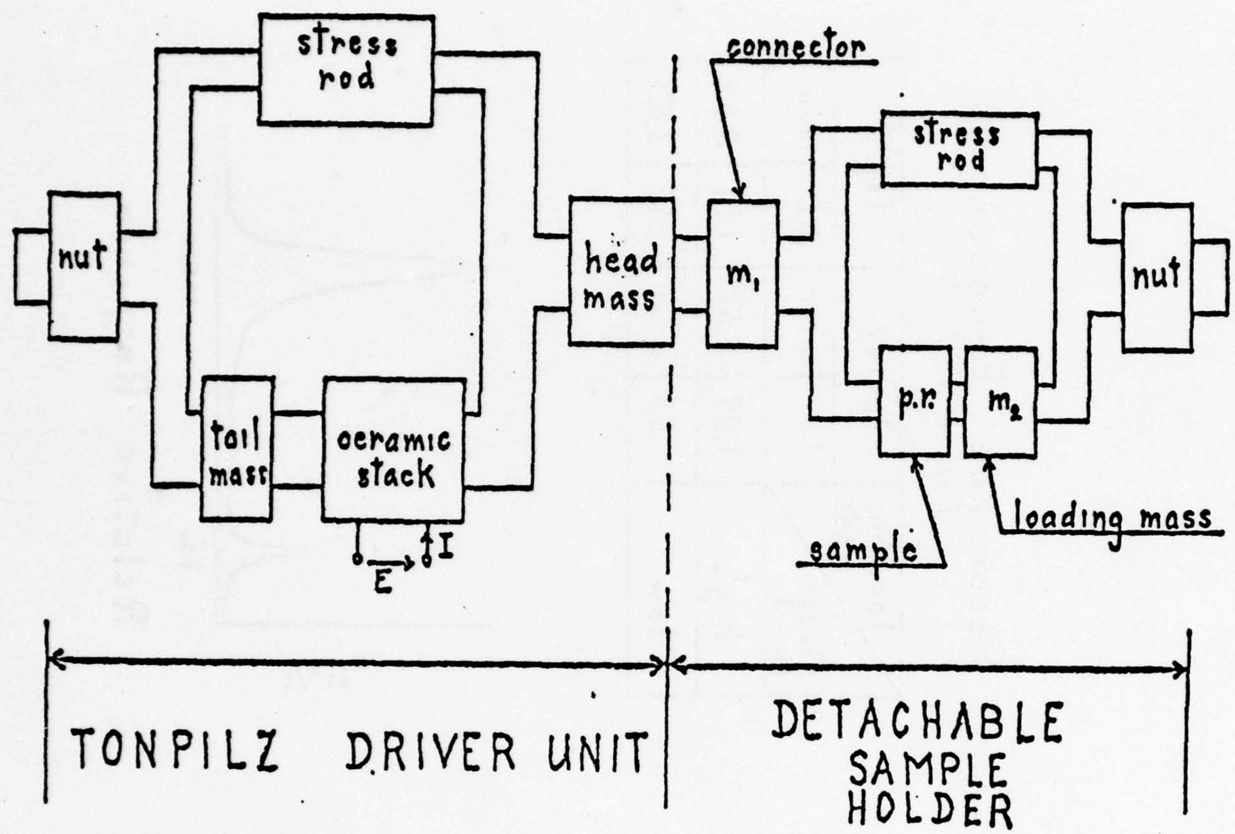


Figure 5.3
BLOCK DIAGRAM

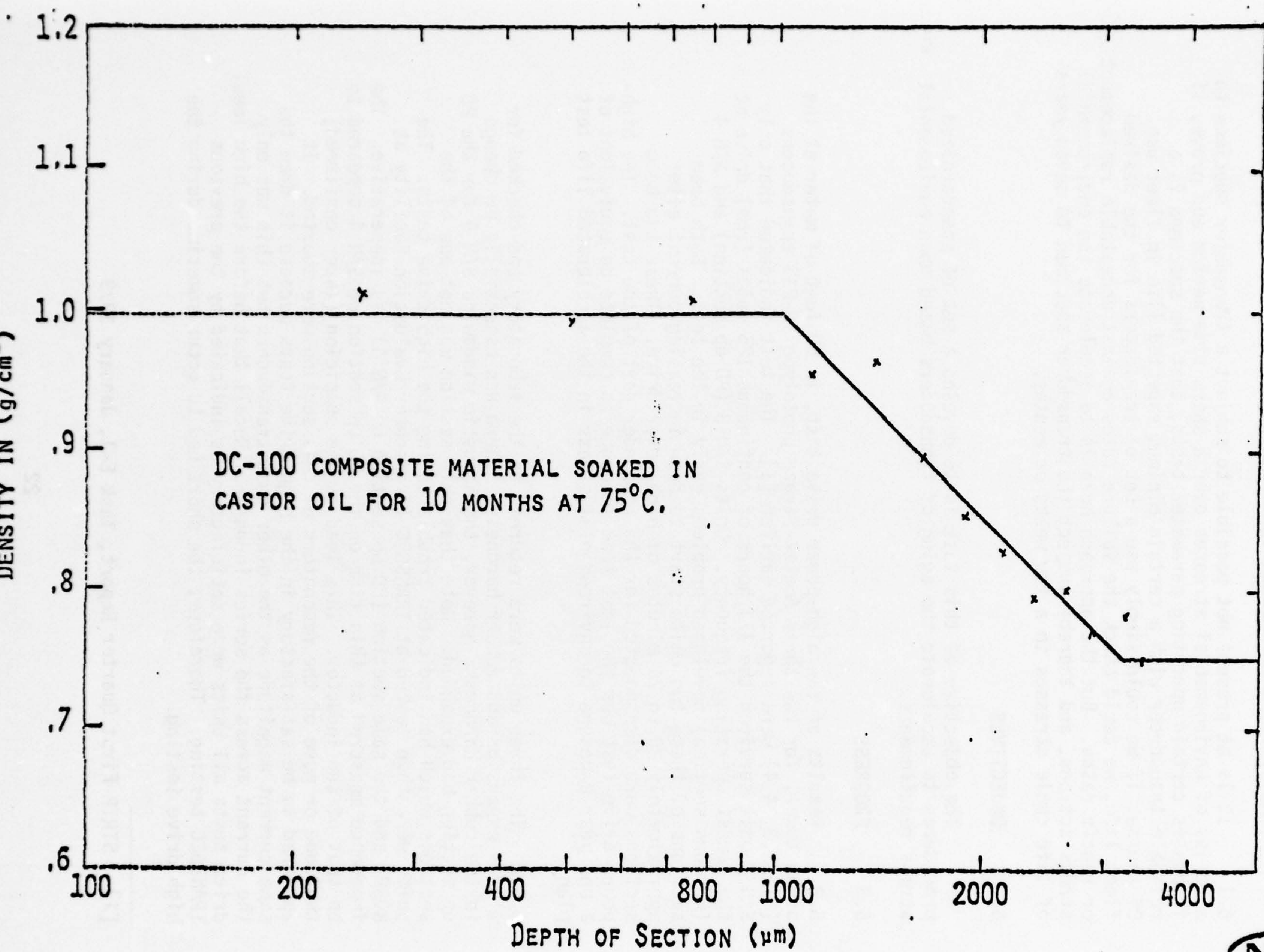


Figure 5.4
OIL PENETRATION DEPTH

6. TASK E-1. STANDARDIZED TEST PROCEDURES

6.1 It is at present not possible to subject a transducer specimen to a series of environmental stresses over a short time period and prove, if it passes certain operating parameter tests, that the specimen is a reliable transducer with a certain minimum expected life in fleet use. Of course, if we could simply use a set of transducers for the desired fleet life, we could check the failure rates against acceptable replacement or repair rates. But the approach here is to accelerate the environmental stress actions, and thereby subject the transducer specimen to seven years of life cycle stresses in a few weeks or months.

6.2 OBJECTIVES

The objective of this task is to develop a set of standardized procedures to accelerate the aging of transducers based upon enviromental *sic* stress requirements.

6.3 PROGRESS

6.3.1 Results of the high-power drive test, in 60 feet of water at the ocean tower, for the three Ametek-Straza prototype TR-215 transducers (S/N 2,3, & 4) were reported earlier [1]. The test indicated that only S/N 2 unit survived the 171 hours of continuous 125 volts (rms) drive at the lowest operating frequency. Units S/N 3 (PD up section) and S/N 4 (PD down section) developed problems early in the test. Both beam sections of these two units start to draw increasing current after approximately 20 to 75 minutes of high-power drive. These two beam sections were disconnected for the remainder part of the test. The high-power drive test was the last test sequence to complete an equivalent of a one year exposure to environmental stress in the accelerated life test plan.

6.3.2 The three units were returned to the laboratory and checked for window expansion and rubber hardness. There was essentially no change in the rubber hardness; however, the acoustic window on S/N 4 for the PD up section had expanded. Note that this section was not one of the sections which had indicated trouble during the high drive tests. The units were then tested at TRANSDEC (Transducer Evaluation Facility at NOSC) and the same section (PD up section on S/N 4) was inoperative. The impedance measured at this time on the PD up section of S/N 4 appeared to be that of the inductor. This lead to the suspicion (later confirmed) that one or more of the resonators of this section were shorted. It appeared to be satisfactory in the high drive tests because it drew the same current magnitude as the other good transducers but this was only the current across the series inductor. Recall that before the high level drive tests all units were satisfactory as indicated by the previous TRANSDEC testing. Therefore, the short had to occur sometime during the high drive testing.

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[1] STRIP First Quarter Report, Task E-1, January 1979

It also was found at TRANSDEC that the section which had drawn excessive current proved to be satisfactory at low levels (10 volts drive) as indicated by all of the TRANSDEC testing (recall these sections are the PD up section on S/N 3 and the PD down section on S/N 4).

S/N 3 transducer was returned to TRANSDEC mounted horizontally on its side at a depth of 6 meters, and the PD up section was driven at high drive (125 volts rms). A 5 amp limiter was placed on the current and the unit behaved as it had at the tower. Within 15 minutes to an hour it had drawn up to the limit of 5 amps. Prior to this high drive test the patterns and the source level at low drive had been checked and found normal. Approximately 10 minutes after the high drive test, after sufficient time for cooling, it was found that the current was again normal. It was thought that perhaps the depth was insufficient in TRANSDEC and that cavitation had accounted for the heating. Therefore, the drive level was reduced from 125 volts rms to 90 volts rms and the unit driven at this level. Only a slight rise in current was observed before stabilization. A further check convinced the experimenters that if the unit was lowered to the bottom of TRANSDEC (approximately 11.6 meters), cavitation would not be a problem. However, there was insufficient pipe to lower the unit to the bottom of TRANSDEC, therefore a chain was used. This resulted in S/N 3 now being mounted vertically but with the PD up section at the highest point on the vertical transducer. High drive testing was resumed, the current quickly rose to high levels, and this time the 5 amp limit was removed. At a drive level of approximately 10 amps the unit took a sudden change, became inductive, the current dropped back to "normal" and the section was now inoperative acoustically.

The unit was returned to the shop, dismantled, and it was discovered that the resonator which would have been at the lowest point of the PD up section during the vertical suspension high drive tests (at which time the unit failed) was the resonator that broke. The piezoelectric material had cracked apparently due to excessive heating of the silguard and the consequent expansion. The resonator in the uppermost position also showed signs of problems, namely the head had begun to crack.

Review of the previous statements tends to discredit the theory that air bubbles in front of the radiating heads were the cause of problems associated with rising current versus time. Previously it was thought that the moving around of the transducer had probably moved the bubbles in and out of the detrimental position in a manner to corroborate the theory that the air bubbles were the cause of the heating. However, as indicated above, while the transducer was in a fixed horizontal position, on its side, the patterns and source level at low level appeared normal. Yet the problem due to heating appeared even though the transducer had not been repositioned (magically moving the bubbles into place). It is now conjectured that the theory that problems are due to the rubber window not being sufficiently separated from the head. The fact that in some cases only a thin oil film exists between the head and the rubber window may account for a non-linear explanation of the problem. Specifically, it could be that at low levels the thin oil film operates satisfactorily as a coupler between the head and the rubber window.

However, as the drive level is increased a non-linear condition is reached at which the oil begins to heat and the thin film of oil turns into a vapor. This results in a decoupling of the head from the rubber. The consequent heating of the piezoelectric material changes the impedance in such a way as to make the current rise and ultimately destroy the resonator.

Simultaneously while testing the S/N 3 PD up section (while the unit was suspended vertically on a chain) the PD down section was operated at high drive levels. However, recall that the PD down section in this vertical position had actually been positioned at the low point on the transducer. For the first 30 minutes or so the current level seemed normal just as was experienced during the 1½ hour in which the PD down section of S/N 3 had been driven at the tower. By the time 40 minutes had passed the current had risen from a more or less normal value of 2.2 amps to 3 amps. In the next approximately 10 seconds the current rose from 3 amps to 6 amps and then the element went inductive. Going inductive is a well known symptom of a short of a resonator. The unit was dismantled in the laboratory. It was found that in the position at which the unit had physically been mounted the uppermost two resonators in the PD down section had been broken. The piezoelectric ring had been broken, the same as the one unit in the PD up section of S/N 3.

Some of the resonators which had cracked ceramic showed that the silguard had extruded through the tiny hole or groove originally intended for oil filling of the cavity in the resonator. This and other indications lead to the strong conjecture that heat expansion of the silguard ultimately leads to the cracking of the piezoelectric rings.

No further results or problems directly attributable to high drive at TRANSDEC were noted. However, recall that all sections of S/N 2 transducer survived the full 171 hours high level drive at the ocean tower. This may be attributed to the following set of circumstances. The narrow-beam sections have their resonator elements subjected to lower currents than the PD up and down sections merely because there are more resonators in parallel. The S/N 2 PD down section presented a special case in that during the inspection after the TRANSDEC low drive testing it was noticed that there was a small bump on the rubber window. It was thought that perhaps the stress rod (which physically is a bolt with the screw head side mounted in the radiating face) had broken and was pushing out against the rubber window. However, when the unit was dismantled some of the Armstrong adhesive A2 which is used to cover the slot in the screw head of the stress bolt had been deposited on the back side of the rubber window. There was also evidence of burning in the same general area. It was also noted that the radiating face of this resonator was higher than the others, (it protruded approximately 1/32" further in the direction of the rubber window than the other resonators). Armed with this information it was conjectured that the Armstrong adhesive A2 had been in contact with the rubber window and that local heating had taken place during high drive, softening the Armstrong material and depositing it on the rubber window. Also, a considerable amount of the rubber in that vicinity had been carbonized due to heating. Thus, although this particular unit

apparently did not unload itself in such a way as to cause the problem (with increasing current, consequent heating, and ultimate destruction) there was some non-linear effect taking place on this resonator also. It was postulated that air being in front of the face would cause unloading of the transducer elements which could manifest itself as excessive current being drawn by the transducer (even more than that which could be experienced by a dead short).

It should be noted that the two types of failures, i.e., for S/N 4 unit up and the S/N 3 unit up and down are different. S/N 3 failed with constant running and a buildup of heat and therefore arc-over, whereas the S/N 4 up unit was found to be a dead short and therefore did not sustain physical damage that could be seen on the individual transducer element (five elements are in parallel and only one shorting out would short out the whole unit). Since the S/N 3 units indicated as defective were brought up in voltage gradually at TRANSDEC, to try to simulate the failure, these units were subjected to deterioration during tests. Upon opening and examining the S/N 3 up and down units it was found that extreme damage had occurred both on the nodal mounts (deformed due to heat and misalignment) as well as ceramic cracking and arcing. It will also be noted that probably due to the high drive, head cracks developed.

6.3.3 Summary of Test Results

The S/N 2 transducer test results have implications with regard to the overall design. Probably the most significant point is that it proves that the basic design can survive for the full 171 hours high level drive. Therefore it can be concluded that the basic design is not faulty as one would be led to believe from problems experienced in the other units where the current climbs and ultimately causes heating which destroys the element. It is speculated that the expansion of the rubber in the local vicinity of the stress rod head forced the rubber window away from the face sufficiently to allow the oil to enter and partially couple the radiating head to the acoustic medium. This prevented the heating and current rise phenomena and the ultimate destruction of this resonator. Inspections of the disassembled PD up section of S/N 3 unit revealed discolorations in the rubber nodal mount grommets and in the phenolic mounting block in which the grommets fit. This discoloration is believed to be caused by heating. It is noted that the pitting, etc., of the rubber is reminiscent of other conditions known to have been caused by cavitation. It is also noted that there are no electrical wires or terminals anywhere near this vicinity. Therefore the problem could not be associated with electrical phenomena. The tabs are also bent reducing the available distance between positive and negative foils. On the S/N 4 unit which was shorted out it was discovered that the insulation on the wire was pinched when penetrating the nodal mount and arc over occurred to the metal portion of the nodal mount. The distorted nodal mount grommet is an indicator of the contributing effect of the pinched mount to the problem.

In general the failure mode analysis and accelerated life test planning have uncovered many potential problems, some of which were verified during the accelerated life testing.

6.3.4 All three partially diassembled TR-215 were returned to Ametek-Straza in January 1979 for repair. The repaired units (S/N 2, 3, & 4) and one TR-215 first article unit (S/N A2) were returned to NOSC in later February. From previous experience of air entrapment it was decided to place these four units in the oven at 71°C (160°F) overnight (16 hours) to drive out any air that may be in the units toward the radiating faces before performing the low level baseline acoustic tests. Air bubbles were detected by probing in at least one beam section of each of the four units five hours after the oven test. In addition, the PD up section of S/N 3 unit leaked oil in the rubber window. All four units were returned to Ametek-Straza.

Three units, S/N 2, 4, and A2 (first article unit) were returned to NOSC by Ametek-Straza and sent to TRANSDEC for low level baseline acoustic test. Low level (10 V rms) beam patterns and transmit voltage responses of the three units were within specification. However, preliminary high power drive tests (100 V to 125 V rms) at TRANSDEC indicate that both the PD up and PD down beam sections of S/N 4 and S/N A2 and the PD down beam section of S/N 2 still have the same problem of drawing excessive current (overheating) after less than one hour of high power drive.

6.3.5 An interim report on the first year of accelerated life testing on the prototype TR-215 transducers is being completed.

6.4 PLANS

6.4.1 There is still a need for further investigation to determine specifically the cause of the decreasing input impedance in the wide beam sections of the TR-215 transducers which results in drawing excessive current, consequent heating and ultimate destruction at high power drive levels.

6.4.2 The continuous high power drive with 125 V CW inputs at the lowest operating frequency may be too severe for the transducers. The normal operation of the transducers uses a continuous linear frequency sweep across the operating band which requires a lower average power. A two-second continuous linear frequency sweep across the operating band at 125 V will be attempted to determine whether the problem of drawing excessive current still persists.

6.4.3 Continue with the second year of accelerated life testing on the TR-215 ( ). Commence with the first year of accelerated life testing on two first article TR-215 ( ) and two DT-605. At this date no TR-242 transducers have been received for testing.

7. TASK F-1. NOISE AND VIBRATION

7.1 BACKGROUND

As submarine platforms become quieter and sonar systems become more sensitive, problems associated with transducer self-generated noise become more acute. The very real problem of transducer produced noise has already been highlighted. Transducer self-noise can block out that transducer's operation as well as radiate out into the medium. Radiated noise can also interfere with other acoustic systems of a ship or submarine. Because of those problems, all new or improved transducers should be scrutinized for noise sources. At present there are no fully accepted methods for correlating the radiated noise from an installed transducer with the results of a laboratory test for noise.

7.2 OBJECTIVES

The objectives of this task are to:

a. Review and evaluate existing transducer self-noise criteria.

b. Isolate and analyze sources of self-generated noise in transducers.

c. Develop analytical criteria and test methods for evaluating transducer radiated self-noise.

d. Apply radiated self-noise criteria and test methods to sonar transducer standards.

7.3 PROGRESS

7.3.1 Application of minimum detectable source level to transducer acceptability tests

In the STRIP Second Quarter Report, Task F-1 of April 1978, worst case conditions were postulated to establish a minimum detectable source level for transducer radiated self-noise. The characteristics of transient noise mentioned in that report that affect detectability, were:

a. energy content,

b. time duration, and

c. spectral content.

Another characteristic that should be a part of this list is the frequency of occurrance. A single impulse may be detectable, but if more than one impulse is not detected within a limited time period, the first detection would probably be dismissed by a sonar operator as being unimportant. However, if many such impulses were detected within a short time period, the chances of the detection being acted upon are greater.

Therefore, the number of times the transducer impulse noise exceeds the minimum detectable source level, SL (min), per unit time period is an important consideration.

To suggest a method for testing transducers for compliance with the radiated self-noise criteria as suggested previously, and to take into account the frequency of occurrance, it would be advantageous to match the test method as closely as possible with the assumptions used in developing the criteria. Ideally, this means that since the assumption of an optimal detection system is used to develop the criteria, an optimal detection system should be used to test the transducer for compliance with the criteria. In Figure 7.1, it would be nice if an array could be positioned a specified number of meters away from the transducer under test and the transducer raised and lowered in much the same way it would on a submarine during actual operations. The transducer radiated self-noise picked up from this array would be filtered, whitened in accordance with a standard sea state curve, squared, and integrated to calculate the total energy in each impulse. This energy would then be compared to different energy level thresholds which are referenced to the minimum detectable source level. When the total energy of a single transient exceeds a threshold, the sum stored in the event counters would increment by one. The total number of times each energy threshold is exceeded by a particular transducer during a specified time period, would be compared to an acceptance criteria previously established to evaluate that transducer's self-noise.

The test method of Figure 7.1 implies that the testing should be performed with an array to monitor the transducer radiated self-noise in a free field. If many tests or pressure cycles are necessary, this method of monitoring the self-noise of transducers is neither economical nor practical. The only practical method of pressure cycling transducers for many cycles is with a pressure tank. This does not mean that free-field measurements should be discarded. Free-field measurements would still be needed to verify the results of pressure tank measurements and to help calibrate pressure tank systems. The test method of Figure 7.1 can be simplified with a single hydrophone replacing the array and compensating the loss in array gain by positioning the single hydrophone closer to the transducer under test, thereby offsetting the array gain by having proportionately less propagation loss. Analysis of a transducer's self-noise in a free field would be needed to determine the average time duration of impulses, and the bandwidth and flatness of the energy spectral density (ESD). The results of a free-field test can be used to set the test parameters, and the method of Figure 7.1 can be applied to pressure tank testing with a hydrophone in the pressure tank with the transducer under test replacing the array or hydrophone in a free field.

7.3.2 TR-215 radiated self-noise measurements

In the STRIP FY79 First Quarter Report, Task F-1, the methods used to analyze the radiated self-noise of the cut-down sections of the new and old TR-215's were presented and explained. Figure 7.2 is a

representative sample of the results of those tests. In this figure, 576 self-noise transients were detected during a twelve-minute period and the average ESD calculated. SL (min) is the minimum detectable source level as calculated in the STRIP Second Quarter Report, of April 1978. The line which resembles an exponential decay is SL (min) when whitening for a reference sea state curve is used instead of the sea state curve value at a single frequency. In Figure 7.2 it appears that the self-noise of the TR-215 is detectable when compared to SL (min). but this is not true. No attempt has been made to convert the ESD from a pressure tank, near field measurement at approximately 10 centimeters, to a far field, free measurement at one meter, because of the uncertainty of the validity of the results when this is done. However, if simple spherical spreading loss is applied to the ESD of Figure 7.2, then an additional 19 dB could be subtracted from the overall energy level. In addition, it is felt that the reflections from the surfaces of the pressure tank along with the effects of measuring the noise in the near field would tend to make the ESD measurement higher in level than a corresponding free-field measurement. Therefore, the radiated self-noise of the TR-215 does not appear to be detectable with this worst case assumption.

7.3.3 Free-field measurements test plan

Plans have been prepared to use the test vehicle described in the First Quarter Report, 1979, for free-field measurements of the radiated and electrical self-noise of the TR-155 and TR-215 at Lake Pend Oreille, Idaho, during the month of July, 1979. The tests would proceed as follows:

a. test vehicle self-noise measurements (first day),

b. test vehicle and system calibration (second day),

c. TR-155 and TR-215 radiated and electrical self-noise measurements (third day).

During these tests three monitor hydrophones would be mounted directly to the test vehicle and would monitor the radiated self-noise of the vehicle and transducers from a known fixed position in the near field while the vehicle is being lowered and raised in the lake to maximum depths of 800 to 1,200 feet. Two additional monitor hydrophones would be lowered to depths of 200 and 400 feet respectively at a known distance from the test vehicle path to monitor the far field radiated self-noise. When the transducers are being tested the electrical outputs will also be monitored. This will give three independent readings of the TR-155 and TR-215 self-noise from 6 separate sources:

a. the transducer electrical outputs,

b. three near field monitor hydrophones, and

c. two far field monitor hydrophones.

7.3.4 Crane tests

The Quiet Pressure Testing Facilities at Crane have made possible the discovery of potential problems with monitor hydrophones used as standards to measure the self-noise of pressure tanks and transducers. Three of the four hydrophones sent to Crane have exhibited varying levels of their own self-noise when undergoing pressure changes. This self-noise has occasionally been significant enough to change the results of pressure tank and transducer tests. Six additional hydrophones of the same type used by Crane, have been acquired and will be tested at the Crane facility. These hydrophones will be rated according to their "quietness".

7.3.5 Transducer piece-part tests

The small pressure tank set-up for piece-part self-noise measurements is still awaiting shipment of parts necessary for noise and vibration isolation. A monitor hydrophone has been installed and calibrated and the pressure tank is ready for calibration. A small transducer source has been built and calibrated and will be used to inject a known signal pulse into the pressure tank system. Once the overdue parts arrive the tank will be calibrated and made ready for piece-part testing.

7.4 PLANS

During the next quarter the following will be accomplished:

a. A technical report will be published (TR #397) on the minimum detectable source level criteria for sonar transducers radiated self-noise. This report will include a summary of the pressure release material (Sonite), and TR-215 radiated self-noise analysis results.

b. A separate technical report will be published (TN #647) which will cover in detail the analysis and results of the TR-215 piece-part testing (i.e., Sonite and TR-215 center section).

c. The newly acquired monitor hydrophones will be tested at Crane for quietness and the hydrophones rated accordingly.

d. The piece-part instrumentation and test apparatus will be calibrated and testing on NRL/NUSC supplied pressure release material will begin as soon as the required parts are received.

e. Preparations will continue for inital free-field testing in July at Lake Pend Oreille.

OPTIMAL DETECTION SYSTEM (FOR USE IN TRANSDUCER RADIATED SELF-NOISE EVALUATION)

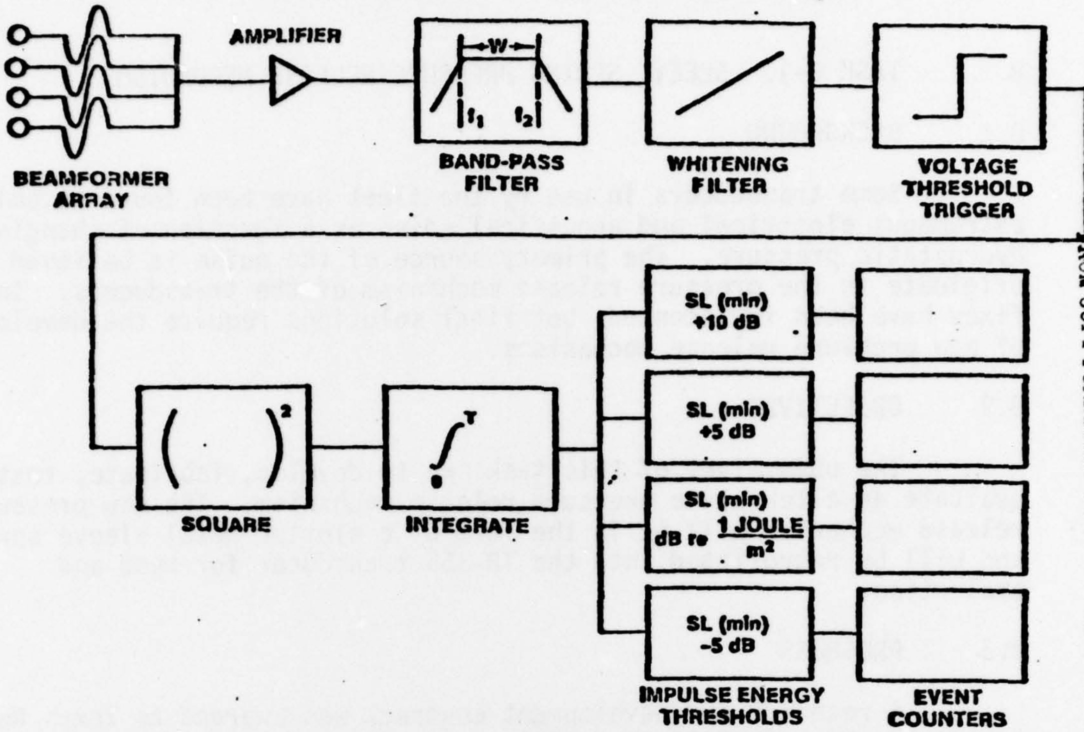

Figure 7.1

SEPT 78
TR-215 (NEW) RADIATED SELF-NOISE AVERAGE (ENERGY SPECTRAL DENSITY)

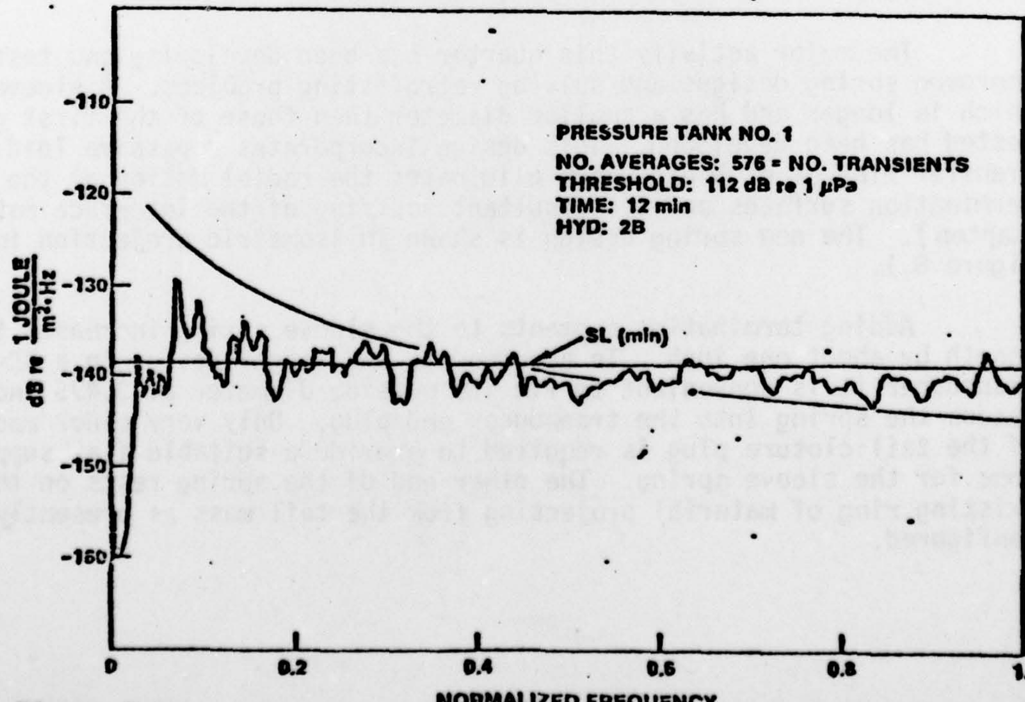

Figure 7.2

8. TASK G-1. SLEEVE SPRING PRESSURE RELEASE MECHANISM

8.1 BACKGROUND

Some transducers in use by the fleet have been found to emit extraneous electrical and acoustical noise as a function of changing hydrostatic pressure. The primary source of the noise is believed to originate in the pressure release mechanism of the transducers. Interim fixes have been implemented, but final solutions require the development of new pressure release mechanisms.

8.2 OBJECTIVES

The objectives of this task are to develop, fabricate, test, and evaluate an alternative pressure release mechanism. The new pressure release mechanism will be in the form of a slotted metal sleeve spring and will be retrofitted into the TR-155 transducer for test and evaluation.

8.3 PROGRESS

A research and development contract was awarded to Texas Research Institute, Inc. (N00173-78-C-0156 of 17 July 1978) to accomplish the stated objectives. Most of the initial effort was used for a theoretical stress analysis of the spring configuration and mechanical evaluation of a first test spring. The results were reported in the STRIP FY78 Fourth Quarter Report.

Last quarter, a lot of time was spent attempting to measure the dynamic stiffness of the sleeve spring. As a result, other task areas suffered and fell behind schedule. Progress this quarter, however, has been dramatic.

The major activity this quarter has been developing and testing improved spring designs and solving retrofitting problems. A sleeve spring which is longer and has a smaller diameter than those of the first group tested has been developed. This design incorporates a passive load transfer ring at each end which eliminates the radial motion at the spring termination surfaces and the resultant scuffing of the interface material (Kapton). The new spring design is shown in isometric projection in Figure 8.1.

Adding termination segments to the sleeve spring increases its length by about one inch. To accommodate the longer design in a TR-155 transducer it is convenient to fix its outside diameter at 3.475 inches and recess the spring into the transducer end plug. Only very minor machining of the tail closure plug is required to provide a suitable flat support zone for the sleeve spring. The other end of the spring rests on the existing ring of material projecting from the tail mass as presently configured.

Spring testing has proceeded along several fronts during this reporting period. This includes fatigue testing, stiffness evaluation, strain gauge monitoring, and photoelastic studies using plastic spring models and polarized light. Two final version retrofit candidate springs have been cycled through minimum axial loadings of 2000 pounds and maxima of 20,000 pounds 100 times. One closely related design (O.D. 25 mils smaller, load transfer web 56 mils wider) was subjected to a full 5000 cycle fatigue test also involving loading from 2000 to 20,000 pounds. This full fatigue test left the spring unaltered in both flexural properties and physical dimensions. Strain gauge evaluation of the most heavily stressed zones of typical sleeve springs has been very consistent with Instron stress-strain profiles in terms of identifying the onset of yielding in springs that have not been heat treated. Extrapolating this information to heat treated units confirms that present spring designs are conservatively tailored to the TR-155 application.

Photoelastic studies of two acrylic spring models have been carried out. This type of procedure is not quantitative but does provide a very appealing way of visualizing stress distributions qualitatively. Again the results are encouraging in that it is apparent that most of the volume of a sleeve spring contributes to the storage of strain energy in the flexural system.

Current sleeve springs are being built to exhibit a static (Instron measurement) stiffness of 300,000 pounds per inch. This is the value Honeywell claims is the dynamic (effective property in an oscillating spring-mass system) stiffness of present TR-155 Belleville springs. 300,000 pounds per inch is also the stiffness established by NUSC-New London as a design objective for alternative TR-155 pressure release systems. There is no particular difficulty in meeting this objective for sleeve springs. The question of just how satisfactory the objective is remains. Dynamic stiffness work under this contract has not been successful in resolving this question. However, some additional information has arisen. Ted Mapes of NUSC-New London has had two modified TR-155 transducers evaluated acoustically at USRD. One of these had a Hytrel puck operated in uniaxial compression. The other unit was fitted with a flexural disc spring. Both pressure release systems were designed to exhibit static stiffnesses of 300,000 pounds per inch. USRD measurements indicated that the low frequency resonance in the receive sensitivity of these units occurred at a frequency somewhat higher than desired. The implication seems to be that the effective dynamic stiffness of current lubricated Belleville pairs is actually lower than presently estimated. This foreshadows an interest in sleeve springs which exhibit stiffnesses lower than 300,000 pounds per inch. Although fabricating more compliant units lies outside the scope of the present contract, there are indications that the sleeve spring configuration allows considerable latitude in meeting the more demanding strain energy storage requirements of that application.

Testing of the new spring design with both Kapton and polyester interfacing materials was also carried out during this reporting period. This included observing the effects of 5000 load cycles between 2000

pounds minimum and 20,000 pounds maximum in conjunction with a full spring fatigue test. The three mil thick Kapton film came through this almost unmarked. A good bit of scuffing and embossing (but no cut through) of the 4 mil polyester was apparent. The test was not entirely unbiased. Kapton samples were placed under the four maximum load zones of the sleeve spring always held in place at least by the weight of the spring. A sheet of polyester was placed on top of the spring and allowed to migrate somewhat when the test system was unloaded to allow lubricant to be distributed on the drive screws of the Instron. Probably either material is adequate but the Kapton is clearly a very rugged material well suited to the sleeve spring interfacing application. With the selection of Kapton, the interfacing material evaluation task is considered closed. Kapton will be used in all retrofitted transducers.

In the retrofitted configuration, the tuning inductor is re-potted in a cylinder which is attached to one end of the spring at the passive load transfer ring. The first retrofitted TR-155 was completed by TRI on schedule but the noise tests have been delayed due to the backlog of higher priority work at NUSC/NLL. All six retrofitted transducers are being completed and are now scheduled for noise tests to begin in mid-April.

8.4 PLANS

Upon completion of the noise tests, the retrofitted transducers will be evaluated acoustically at NRL/USRD. The final report from TRI will be completed during the next quarter.

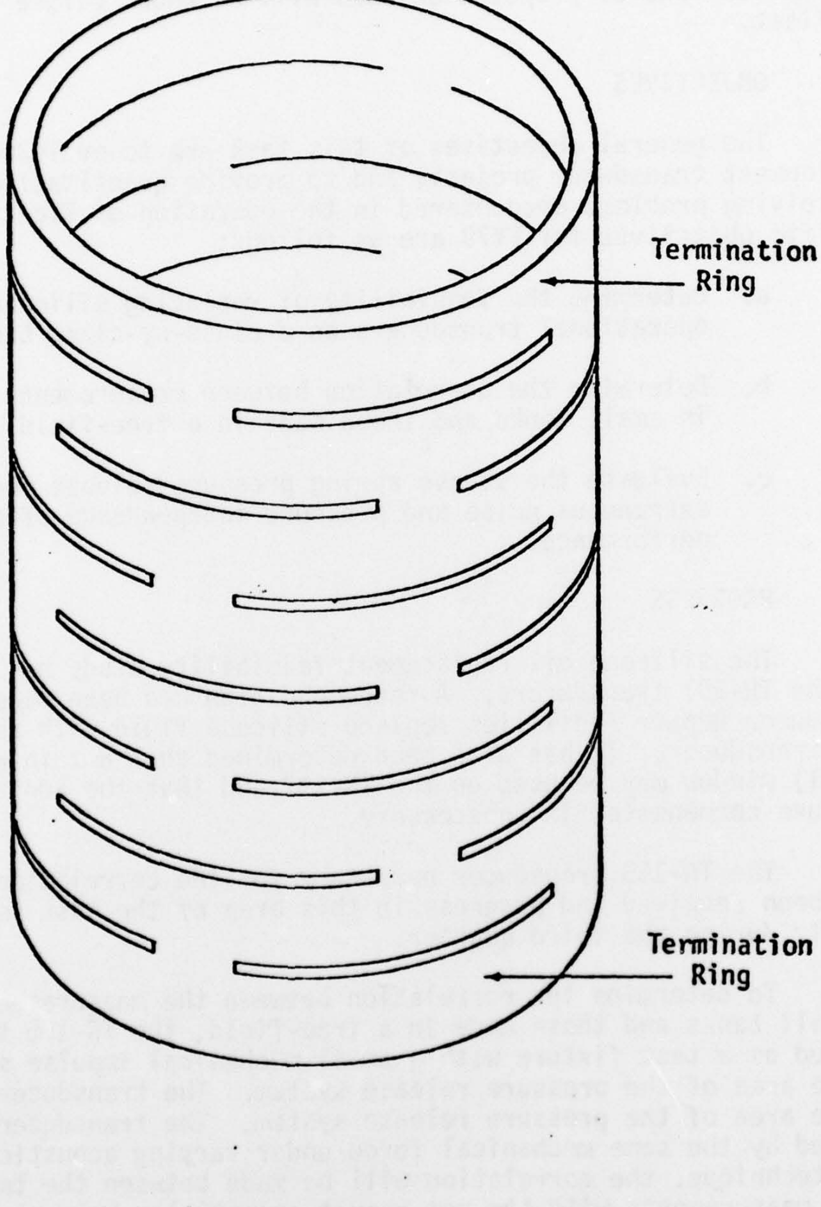

Figure 8.1

SLEEVE SPRING--ISOMETRIC PROJECTION

9. TASK G-2. TEST AND EVALUATION

9.1 BACKGROUND

The improvements in engineering developments, the development of new test methods, and the new specifications and standards achieved must be utilized to assemble, test, and evaluate prototype transducers so that all implications of proposed changes will be known before introduction to the fleet.

9.2 OBJECTIVES

The general objectives of this task are to evaluate new engineering development transducer projects and to provide quantitative alternatives for solving problems encountered in the operation of fleet sonar systems. Specific objectives for FY79 are as follows:

a. Determine the feasibility of replacing silicone fluid in operational transducers on a class-by-class basis.

b. Determine the correlation between measurements of noise made in small tanks and those made in a free-field.

c. Evaluate the sleeve spring pressure release mechanism for extraneous noise and pressure independence of acoustic performance.

9.3 PROGRESS

9.3.1 The silicone oil replacement feasibility study has been completed for the TR-297 transducers. A recommendation has been made that the Transducer Repair Facilities replace silicone fluid with castor oil in this transducer. It has also been determined that a thin metal (copper/nickel) window may be used on the TR-297 and that the addition of a pressure compensator is unnecessary.

9.3.2 The TR-155 transducer necessary for the correlation experiment has just been received and progress in this area of the task is expected rapidly during the third quarter.

To determine the correlation between the measurements of noise made in small tanks and those made in a free-field, the TR-155 transducer will be used as a test fixture with a small mechanical impulse source attached in the area of the pressure release system. The transducer may then be in the area of the pressure release system. The transducer may then be excited by the same mechanical force under varying acoustic loads. With this technique. the correlation will be made between the tank and free-field measurements with the net result essentially being a "calibration" of the various measurement systems.

Progress in this area is approximately one quarter behind schedule primarily due to late delivery of instrumentation.

9.3.3 Fabrication and retrofitting of the sleeve spring into six TR-155 transducers has been completed under contract to Texas Research Institute, Inc. Due to the backlog of higher priority work at the NUSC/NLL Quiet Pressure Test Facility, all six transducers will be tested simultaneously instead of testing a single prototype first as originally planned.

After undergoing the noise test the transducers will be evaluated acoustically at NRL/USRD.

9.4 PLANS

9.4.1 A final report will be completed in the very near future in which the performance of the TR-297 is compared with the present specifications. The report will also make recommendations for new specifications. A silicone oil replacement feasibility study for the TR-122 will be completed by the end of the fourth quarter.

9.4.2 Correlation measurements are expected to begin within a few weeks with the remainder of the third quarter being used to collect and analyze impulse response data as a function of acoustic boundary conditions. The measurements and a final report documenting the results will be completed by the end of the fiscal year.

9.4.3 The TR-155 transducers retrofitted with the sleeve spring are scheduled to begin noise testing at NUSC/NLL in mid-April. All evaluation measurements should be completed by the end of the third quarter. A final report on the evaluation of the sleeve spring pressure release mechanism is expected to be completed during the fourth quarter.

10. TASK G-3. ENGINEERING DOCUMENTATION

10.1 BACKGROUND

It has recently become apparent to all facilities working with sonar transducers, that many problems are occurring which possibly could have been avoided. Problems with sonar transducer repair, production and/or testing have been repeated year after year simply because facilities did not see that research and development were needed. The lack of research and development can also be attributed to the fact that facilities have had very little interaction and possible solutions to problems encountered were not well documented. With the increasing numbers of sonar transducer types and acquisitions it will be necessary to know the existing and future needs for research and development. A task has been set aside for researching the severity of sonar transducer problems and establishing possible research and development projects.

10.2 OBJECTIVES

The objectives of this task are:

a. To establish the existing and future needs for sonar transducer research and development.

b. To produce a timetable for research and development programs that relates to sonar transducer acquisitions.

10.3 PROGRESS

Work is continuing in the form of a literature search and data acquisition to establish the existing and future needs for sonar transducer research and development. Numerous people have provided input, and a preliminary list of projects throught to be important follows:

Water permeation into transducers and elastomers
Failure modes due to water in transducers
Ceramic lifespan
Encapsulation materials
Corona reducing coatings
Design parameters for preamplifiers
Improved cables and connectors
Design evaluation of UQN-1/4, BQN 17, DT-513A
Potting compounds
Fluids for towed arrays
Shrink tubes for in-line splices
Rubber specifications and accelerated life testing
Baffle materials
Accelerated life testing of DT-513A
Water permeation of potted cavities
Noise generation by fiberglass and ceramics under stress
Identification of electrically weak transducers
Transducer insulation aging

Secondary noise generation by materials
Design evaluation for TR-212 (replacement)
Design evaluation for DT-365 (replacement)
Design evaluation for TR-155 (make it noise-free)
Handbook of insulation materials for transducers
Handbook of transducer structural materials
Handbook of cable and connector designs
Optic fiber cables
Design evaluation for WQC-2
Design evaluation for WLR-9/12
Revision of compendium requirements
Accelerated aging of plastics
Accelerated aging of adhesives
Environmental parameters in accelerated aging
Improved design of the DT-276
Development of a new Rho-C rubber
Accelerated life testing procedures of cables
Accelerated life testing procedures of connectors
Accelerated life testing of transducer protective coatings
Updating of cable testing procedures
Design specification for PZT ceramics
Determination of ceramic shape effect on coupling factor
Determination of advantages of urathane vs neoprene
Determination of cold flow of rubber jacket to cable at hull penetration
OH effects on rubber
Use of gelled polymers for acoustic coupling
Test for effectiveness of coatings and primers
Laminated membranes for permeation barriers
Accelerated life test of butyl in oil
Specification for material and fabrication of the portsmouth connector

It would be very helpful, and much appreciated, if those engineers, scientists, and technicians who are concerned with this program would provide their comments about this list. All clarifications, additions, substitutions, and suggestions for deletions are needed to make the STRIP as relevant as possible.

The order in which these various projects will be undertaken depends in part upon long-range transducer acquisition plans. A schedule of sonar transducer acquisitions and restorations has been completed and organized, but is not included here because of security and procurement regulations.

10.4 PLANS

The objectives of this task for FY79 should be accomplished in the Third Quarter.

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